Section 5.0 EVAPORATIVE EMISSIONS

The following sections detail the EMFAC2000 methodologies for running loss, hot soak, and diurnal/resting loss emissions.

Running losses are evaporative emissions that emanate from hoses, fittings or canisters, while the vehicle is being operated. This can either occur because fuel heating has caused the vapor generation rate to exceed the vehicle's capacity to control the vapors, or through permeation and leakage. Section 5.1 discusses a study, which shows that running losses have a strong dependence on engine operating time, with emissions increasing the longer the engine is running. This makes sense because engine time-on is directly related to fuel temperature.

Hot soaks are evaporative emissions that occur immediately after a trip due to fuel heating when a hot engine is turned off. In older vehicles with carburetors, these emissions were attributed to boiling of the fuel in the carburetor float bowl. Newer vehicles experience these emissions from fuel remaining in the engine manifolds when the engine is turned off, or seepage of fuel from injectors when they get old. Additionally, fuel-injected vehicles return hot fuel back to the tank, and this becomes another potential source of hot soak emissions.

Diurnal emissions occur when rising ambient temperatures cause fuel evaporation from vehicles sitting throughout the day. Resting losses, like diurnal emissions, occur when a vehicle is sitting, but are caused by permeation through rubber or plastic components rather than normal daily temperature excursions.

Section 5.1 METHODOLOGY USED IN ESTIMATING RUNNING LOSS EMISSIONS

This section details how the running loss emissions were estimated for gasoline fueled vehicles.

5.1.1 Introduction

Hydrocarbon emissions that emanate from sources other than the vehicle tailpipe, while the engine is on, are referred to as running loss emissions. When the engine is on, leaks in the fuel delivery system or evaporative control system can lead to vapor losses. In general, running loss emissions vary with trip length, the size of any fuel leaks, fuel temperature and volatility, and the condition of the evaporative control system. In MVEI7G, running loss emissions were estimated by determining the average gram per mile rate as measured over three LA-4 cycles. This rate was then adjusted for speed (using running loss speed correction factors), temperature, and fuel volatility as indicated by the Reid Vapor Pressure (RVP). In EMFAC2000, this methodology has been revised to account for the fact that running loss emissions increase with trip length. Longer trips result in more work being performed on the fuel, which increases the fuel temperature, resulting in increased vapor losses.

5.1.2 Methodology

The running loss emission rates are based on a project conducted by the Coordinating Research Council (CRC) during which 150 conforming and 30 malperforming vehicles were tested. The vehicles were tested over a single LA-4 cycle using a 6.6 RVP fuel at an ambient temperature of 95^{o}F. The emissions were recorded modally in one-minute increments for a period of 25 minutes. The malperforming vehicle data set contained vehicles identified as either needing repair or having emissions that were an order of magnitude higher than other vehicles in the same class. In some instances, these vehicles emitted 200-300 grams per test. Fourteen vehicles were removed from the conforming vehicle data set and placed in the malperforming vehicle data set. Tables 5.1-1 and 5.1-2 show the distribution of vehicles by fuel metering system and vehicle type in the conforming and malperforming vehicle data sets, respectively.

Table 5.1-1 Conforming Vehicles

	CARB	PFI	TBI	Total
Car	45	26	8	79
Truck	45	7	5	57
Total	90	33	13	136

Table 5.1-2 Malperforming Vehicles

	CARB	PFI	TBI	Total
Car	20	2	4	26
Truck	15	3	0	18
Total	35	5	4	44

5.1.3 Basic Emission Rates

Three statistical tests (t-test, non-parametric t-test and an analysis of variance) were performed using Statistical Analysis Software (SAS) to determine if the running loss emissions vary by vehicle type. The results of the t-test, which assumes a normal distribution in the data, indicated that the variance in the car and truck emissions is not the same and cannot occur purely by chance. The non-parametric t-test does not assume normality in the data and compares the median emission values from cars and trucks. This test also indicated that the variation in median values couldn't occur by chance alone indicating the need to split the data set into cars and trucks. The analysis of variance compares the variance between cars and trucks to the variance within cars or trucks to calculate an "F" value. A high F value indicates that there is a difference between cars and trucks. Since the number of cars and trucks was not the same, an analysis of variance using PROC GLM was used for unbalanced data sets. The results from this test also indicated that cars and trucks have significantly different running loss emissions. Based on the three tests above, it was determined that cars and trucks should be modeled separately.

Similar analyses were also performed to determine if running loss emissions vary by fuel metering system, i.e. carburetor, throttle body injection (TBI) or port fuel injection (PFI) system. An analysis of variance (using GLM with a Duncan test) indicated that TBI and PFI have similar emissions and that these emissions are different from those of carbureted vehicles. This result was true for both cars and trucks. Hence, carbureted vehicles were modeled separately than PFI/TBI vehicles.

Additional analyses were performed on vehicles within each vehicle type/fuel metering system to see if vehicles with similar average emissions could be grouped into model year groups. Results from the Duncan test within the analysis of variance indicated that carbureted cars can be grouped into 71-76 and 77-90 model year groups, and that carbureted trucks can be grouped into 71-79 and 80-90 model year groups. The analysis indicated that these groupings were not appropriate for either TBI/PFI cars or trucks.

Similar analyses were also performed on malperforming vehicles. The malperforming vehicles were split into two emission regimes to distinguish between deteriorated vehicles (moderate emitters) and high emitters. It is important to note that the magnitude of emissions from moderate and high emitters changes by technology group. For example, a high emitting pre-1970 carbureted vehicle has an emission rate 20 times greater than a high emitting fuel-injected vehicle.

Table 5.1-3 shows the modeled running loss regression coefficients by vehicle type, fuel metering system, and emissions regime. The general form of the running loss equation is:

$$Tot\_HC = A + B*time + C*time^2 + D*Odometer + E*Age \qquad \textbf{(5.1-1)}$$

Where:
Tot_HC is the cumulative running loss emissions in grams.
Time is the engine time-on in minutes.

Odometer is the total mileage accrued by the vehicle.
Age = (calendar year – (model year+1)).

Table 5.1-3 Running Loss Regression Coefficients

				Intercept	Time	$Time^2$	Odometer	Age	
Vehicle Type	Fuel System	Model Yr. Group	Emission Regime	A	B	C	D	E	R-Square
Car/Truck	Carb	Pre-1970	Normal	0.0000000	1.1135000	0	0	0	0.95
			Moderate	0.0000000	1.0850832		0	0	0.74
			High	0.0000000	7.4541372	0	0	0	0.69
Car	Carb	1970-76	Normal	-1.2473406	0.1520645	0	0.000006589	0	0.30
			Moderate	0.0000000	1.0850832		0	0	0.74
			High	0.0000000	7.4541372	0	0	0	0.69
Car	Carb	1977+	Normal	-0.3820283	0.0726256	0	0.000001874	0	0.26
			Moderate	0.0000000	0.0000000	0.03324	0	0	0.58
			High	0.0000000	7.4541372	0	0	0	0.69
Car	TBI/PFI	All Pre-Enhanced Evap	Normal	-0.1115497	0.0223147	0	0	0.00800653	0.36
			Moderate	-0.1294396	0.1113702	0	0	0	0.74
			High	-1.4894734	0.6072166	0	0	0	0.76
Car	TBI/PFI	Enhanced Evap(1)	Normal	-0.0430068	0.0086032	0	0	0.00308684	
			Moderate	-0.0499041	0.0429376	0	0	0	
			High	-1.4894734	0.6072166	0	0	0	
Truck	Carb	Pre-1980	Normal	-1.16413581	0.09926223	0	0.000006450	0	0.37
			Moderate	-4.08642138	0.49482703	0	0	0.13630326	0.68
			High	0	1.71089551	0	0	0	0.82
Truck	Carb	1980+	Normal	-0.30136997	0.0716051	0	0.000001091	0	0.34
			Moderate	-13.45972	0.4778018	0	0	0.95829205	0.67
			High	0	1.71089551	0	0	0	0.82
Truck	TBI/PFI	All	Normal	-0.18308557	0.00961453	0	0	0.0213216	0.59
			Moderate	-2.08792222	0	0.00688	0	0.27679645	0.73
			High	-1.48947344	0.60721658	0	0	0	0.76
Truck	TBI/PFI	Enhanced Evap(1)	Normal	-0.15803071	0.00829881	0	0	0.01840379	
			Moderate	-1.80219466	0	0.00594	0	0.23891747	
			High	-1.48947344	0.60721658	0	0	0	

(1) Appendix 5.1-A details how the emission rates were derived for vehicles subject to the enhanced evaporative standards.
(2) There were no high emitters present in the fuel-injected truck data set. Staff assumed that this rate is the same as that for fuel-injected cars.

The following assumptions were also used in determining the running loss emission rates:

1. The data set analyzed did not contain pre-1970 high emitting vehicles. Staff assumed that this group of vehicles would have the same emission rates as those high emitting vehicles in the 1970-76 model year group.
2. The data set did not contain high emitting fuel-injected trucks. It was assumed that this emission rate is similar to high emitting fuel-injected passenger cars.
3. Appendix 5.1-A shows how the running loss emission rates were derived for vehicles certified to the enhanced evaporative running loss standard of 0.05 grams per mile. The basic premise in estimating the enhanced evaporative emission rates is that these

vehicles will meet the standard at 100,000 miles or at 9-years of age when tested at 105°F using 7.0 RVP fuel.

5.1.4 Calendar Year Specific Emissions

In order to estimate the running loss emissions inventory for any given calendar year, the emissions from each technology group are weighted by the model year specific technology group fractions. Table 5.1-4 shows which technology groups are present in any given model year. This table shows the main technology groups that affect running loss emissions, however, the recent adoption of the near zero evaporative emissions standard for hot soak and diurnal emissions may also indirectly effect running loss emissions even though the running loss standard was not changed. Staff believes that changes made to the evaporative control system to meet this standard may also lower running loss emissions. However, it is difficult to quantify the reduction in running loss emissions without actual test data. Table 5.1-5 shows the model year technology fractions assumed for gasoline fueled heavy-duty trucks.

Table 5.1-4 Model Year Specific Technology Fractions by Vehicle Class

	Technology Fractions For Passenger Cars						
Year	Carb	TBI	PFI	Enh TBI	Enh PFI	Zero Evap PFI	Zev
2008	0.00					90.00	10.00
2007	0.00					90.00	10.00
2006	0.00					90.00	10.00
2005	0.00				18.00	72.00	10.00
2004	0.00				54.00	36.00	10.00
2003	0.00				90.00		10.00
2002	0.00				100.00		
2001	0.00			0.00	100.00		
2000	0.00			0.00	100.00		
1999	0.00			1.20	98.80		
1998	0.00	0.00	0.00	2.40	97.60		
1997	0.00	1.80	48.20	1.80	48.20		
1996	0.00	2.80	67.20	1.20	28.80		
1995	0.00	3.78	86.22	0.42	9.58		
1994	0.00	11.40	88.60				
1993	0.00	28.20	71.80				
1992	0.00	28.20	71.80				
1991	0.00	28.20	71.80				
1990	0.00	28.20	71.80				
1989	0.00	32.00	68.00				
1988	21.90	21.90	56.20				
1987	25.75	25.75	48.50				
1986	29.80	29.80	40.40				
1985	33.90	33.90	32.20				
1984	39.50	38.00	22.50				
1983	46.70	32.30	21.00				
1982	51.50	33.40	15.10				
1981	52.00	33.50	14.50				
1980	62.60	24.70	12.70				
1979	91.50	3.50	5.00				
1978	96.50	1.50	2.00				
1977	98.00	0.00	2.00				
<=1976	100.00	0.00	0.00				

	Technology Fractions For Light-Duty Trucks (T1)						
M_Year	Carb	TBI	PFI	Enh TBI	Enh PFI	Zero Evap PFI	Zev
2008						90.00	10.00
2007						90.00	10.00
2006					0.00	90.00	10.00
2005					18.00	72.00	10.00
2004	0.00				54.00	36.00	10.00
2003	0.00			0.00	90.00		10.00
2002	0.00			0.00	100.00		
2001	0.00			0.00	100.00		
2000	0.00			0.00	100.00		
1999	0.00	0.00	0.00	5.10	94.90		
1998	0.00	0.00	0.00	10.60	89.40		
1997	0.00	8.05	41.95	8.05	41.95		
1996	0.00	12.39	57.61	5.31	24.69		
1995	0.00	21.60	68.40	2.40	7.60		
1994	0.00	25.40	74.60				
1993	0.00	28.20	71.80				
1992	0.00	28.20	71.80				
1991	0.00	32.10	67.90				
1990	0.00	43.80	56.20				
1989	0.00	51.50	48.50				
1988	25.60	25.60	48.80				
1987	33.75	31.95	34.30				
1986	37.60	34.30	28.10				
1985	43.50	38.70	17.80				
1984	53.05	39.35	7.60				
1983	53.65	44.75	1.60				
1982	65.70	30.80	3.50				
1981	76.40	22.50	1.10				
1980	96.30	3.70	0.00				
1979	96.30	3.70	0.00				
1978	100.00	0.00	0.00				
1977	100.00	0.00	0.00				
<=1976	100.00	0.00	0.00				

	Technology Fractions For Light-Duty Trucks (T2)					
M_Year	Carb	TBI	PFI	Enh TBI	Enh PFI	Zero Evap PFI
2008						100.00
2007						100.00
2006						100.00
2005					20.00	80.00
2004	0.00				60.00	40.00
2003	0.00				100.00	
2002	0.00				100.00	
2001	0.00			0.00	100.00	
2000	0.00			0.00	100.00	
1999	0.00	0.00	0.00	5.10	94.90	
1998	0.00	0.00	0.00	10.60	89.40	
1997	0.00	8.05	[illegible]	8.05	41.95	
1996	0.00	12.39	57.61	5.31	24.69	
1995	0.00	21.60	68.40	2.40	7.60	
1994	0.00	25.40	74.60			
1993	0.00	28.20	71.80			
1992	0.00	28.20	71.80			
1991	0.00	32.10	67.90			
1990	21.90	21.90	56.20			
1989	25.75	25.75	48.50			
1988	25.60	25.60	48.80			
1987	33.75	31.95	34.30			
1986	37.60	34.30	28.10			
1985	43.50	38.70	17.80			
1984	53.05	39.35	7.60			
1983	53.65	44.75	1.60			
1982	65.70	30.80	3.50			
1981	76.40	22.50	1.10			
1980	96.30	3.70	0.00			
1979	96.30	3.70	0.00			
1978	100.00	0.00	0.00			
1977	100.00	0.00	0.00			
<=1976	100.00	0.00	0.00			

	Technology Fractions For Medium-Duty Trucks (T3)					
M_Year	Carb	TBI	PFI	Enh TBI	Enh PFI	Zero Evap PFI
2008						100.00
2007						100.00
2006						100.00
2005					20.00	80.00
2004	0.00				60.00	40.00
2003	0.00				100.00	
2002	0.00				100.00	
2001	0.00				100.00	
2000	0.00				100.00	
1999	0.00	0.00			100.00	
1998	0.00	0.00	0.00	0.00	100.00	
1997	0.00	0.00	50.00	0.00	50.00	
1996	0.00	19.74	50.26	8.46	21.54	
1995	0.00	25.38	64.62	2.82	7.18	
1994	0.00	28.20	71.80			
1993	0.00	32.10	67.90			
1992	0.00	43.80	56.20			
1991	0.00	51.50	48.50			
1990	24.30	24.30	51.40			
1989	31.90	30.20	37.90			
1988	30.05	30.05	39.90			
1987	23.90	23.90	52.20			
1986	34.90	34.90	30.20			
1985	44.00	44.00	12.00			
1984	50.00	50.00	0.00			
1983	76.90	23.10	0.00			
1982	97.50	2.50	0.00			
1981	99.00	1.00	0.00			
1980	100.00	0.00	0.00			
1979	100.00	0.00	0.00			
1978	100.00	0.00	0.00			
1977	100.00	0.00	0.00			
<=1976	100.00	0.00	0.00			

Table 5.1-4 (continued)

	Technology Fractions For T4, T5, T6, T7 and T8 Gas fueled vehicles					
M_Year	Carb	TBI	PFI	Enh TBI	Enh PFI	Zero Evap PFI
2008						100.00
2007						100.00
2006						100.00
2005					20.00	80.00
2004	0.00				60.00	40.00
2003	0.00				100.00	
2002	0.00				100.00	
2001	0.00				100.00	
2000	0.00				100.00	
1999	0.00	0.00			100.00	
1998	0.00	0.00	0.00	0.00	100.00	
1997	0.00	0.00	50.00	0.00	50.00	
1996	0.00	19.74	50.26	8.46	21.54	
1995	0.00	25.38	64.62	2.82	7.18	
1994	0.00	28.20	71.80			
1993	0.00	32.10	67.90			
1992	0.00	43.80	56.20			
1991	0.00	51.50	48.50			
1990	100.00	0.00	0.00			
1989	100.00	0.00	0.00			
1988	100.00	0.00	0.00			
1987	100.00	0.00	0.00			
1986	100.00	0.00	0.00			
1985	100.00	0.00	0.00			
1984	100.00	0.00	0.00			
1983	100.00	0.00	0.00			
1982	100.00	0.00	0.00			
1981	100.00	0.00	0.00			
1980	100.00	0.00	0.00			
1979	100.00	0.00	0.00			
1978	100.00	0.00	0.00			
1977	100.00	0.00	0.00			
<=1976	100.00	0.00	0.00			

Table 5.1-5 <u>Technology Fractions for Gasoline Fueled Heavy-Duty Trucks</u>

5.1.5 <u>Regime Growth Rates</u>

A composite emissions rate is calculated by weighting the regime specific emission rates by the fraction of normal, moderate and high emitting vehicles within each technology group. To calculate the regime specific populations by technology group and vehicle odometer, staff analyzed a data set containing tests from projects performed by the USEPA, CARB and the CRC. The CRC data was also used in developing the emission rates. However, this data set was combined with the historical running loss data to increase the amount and diversity of the data used in developing the regime growth rates.

The regime specific populations by vehicle age were determined by analyzing vehicles that were tested using 9.0 RVP fuel and at 95^{o}F. The vehicles were then classified into emission regimes by comparing the total emissions to the predicted emission levels or regime boundaries. The regime boundaries were defined as:

Normal: Vehicles with emissions less than or equal to the upper 95% confidence level (CL) for normal emitters.
Moderates: Vehicles with emissions between the lower 95% CL for highs and the upper 95% CL for normal emitters.
Highs: Vehicles with emissions greater than or equal to the lower 95% CL for highs for vehicles identified as highs.

Ideally, each technology group should have its own set of regime specific growth rates. However, due to a lack of data the regime growth rates were only developed for carbureted and fuel-injected vehicles. Tables 5.1-6 and 5.1-7 show the number of carbureted and fuel-injected vehicles classified as normal, moderate and high emitting by vehicle age, respectively.

Table 5.1-6 shows that between 2-5% of the carbureted vehicles are high emitting. This agrees well with USEPA's[1] estimates for the frequency of liquid leakers, which predicts approximately 5% of the vehicles as being high emitters. In comparison, table 5.1-7 indicates that approximately 32% of the fuel-injected vehicles were high emitting. Upon closer inspection, staff found that vehicles tested by CARB had a higher percentage of vehicles in the high emission regime then those tested by the USEPA. This larger percentage of highs could either result from a recruitment bias or that in earlier technology fuel-injected vehicles; the pressurized fuel system caused more leaks to develop in the evaporative control system. Assuming the former hypothesis to be true, vehicles tested by CARB were excluded in the development of regime growth rates. Ideally, the regime specific populations should be based on random testing of vehicles over a test that is a good indicator of the magnitude of the running loss emissions.

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[1] Evaporative Emissions of Gross Liquid Leakers in MOBILE6, by Larry Landman, Draft, Document Number M6.EVP.009 dated June 20, 1999

Table 5.1-6 Distribution of Carbureted Vehicles by Emissions Regime

Age	High	Modr	Norm	Total
2	0	1	0	1
3	0	1	3	4
4	2	8	14	24
5	0	4	8	12
6	0	35	29	64
7	0	10	8	18
8	3	28	10	41
9	0	8	2	10
10	0	26	5	31
11	0	4	3	7
12	0	7	9	16
13	1	15	5	21
14	1	8	8	17
15	0	5	2	7
16	0	7	2	9
17	0	2	2	4
18	0	4	4	8
19	0	4	2	6
20	1	3	7	11
21	0	10	5	15
22	0	3	7	10
23	0	17	6	23
24	0	3	2	5
25	2	3	5	10
26	0	3	5	8
Total	10	219	153	382

Percent of Vehicles by Average Age					
Age Grp	Ave Age	Number	Norm	Modr	High
2-5	4.15	41	0.61	0.34	0.05
6-10	7.55	164	0.33	0.65	0.02
11-15	13.01	68	0.40	0.57	0.03
16-20	18.16	38	0.45	0.53	0.03
21-25	22.76	63	0.40	0.57	0.03

Table 5.1-7 Distribution of Fuel-Injected Vehicles by Emissions Regime

Age	High	Modr	Norm	Total
2	27	56	18	101
3	51	65	38	154
4	14	50	35	99
5	32	33	12	77
6	31	33	10	74
7	23	24	3	50
8	9	15	3	27
9	0	0	3	3
10	9	5	8	22
11	0	1	2	3
12	0	0	3	3
13	0	2	0	2
14	0	0	1	1
Total	196	284	136	616

Percent of Vehicles by Average Age					
Age Grp	Ave Age	Number	Norm	Modr	High
2-4	2.99	262	0.35	0.65	0.00
5-7	5.87	115	0.22	0.78	0.00
8-10	8.90	34	0.41	0.59	0.00
11-13	11.88	8	0.63	0.38	0.00

The fraction of high emitting fuel-injected vehicles is based on USEPA's estimates for the frequency of liquid leakers. This assessment is based on data collected from the CRC running loss study. Vehicles with emissions greater than 7 grams per mile (six vehicles) were classified as gross liquid leakers. Table 5.1-8 shows the frequency of gross liquid leakers as a function of vehicle age. A logistic function was then developed to match these data points. This equation (5.1-2) predicts the percent of liquid leakers as function of vehicle age.

Fraction of Gross Liquid Leakers = 0.06 / (1 + 120*EXP(-0.4*AGE)) **(5.1-2)**

Table 5.1-8 Frequency of Liquid Leakers

Vehicle Age (yr.)	Sample Size	Frequency (%)
8.84	50	2.00
14.24	39	5.13
22.48	61	4.92

The calculation of regime growth rates is problematic since the number of vehicles in each odometer bin is not the same. To calculate the regime growth rates, the percentage of vehicles in each regime were weighted by the number of vehicles in each age group. This provides more weight where there is more data. Table 5.1-9 shows the regime growth rates by fuel delivery system. The general form of the equation is:

$$F\_reg = A + B * Age \qquad \textbf{(5.1-3)}$$

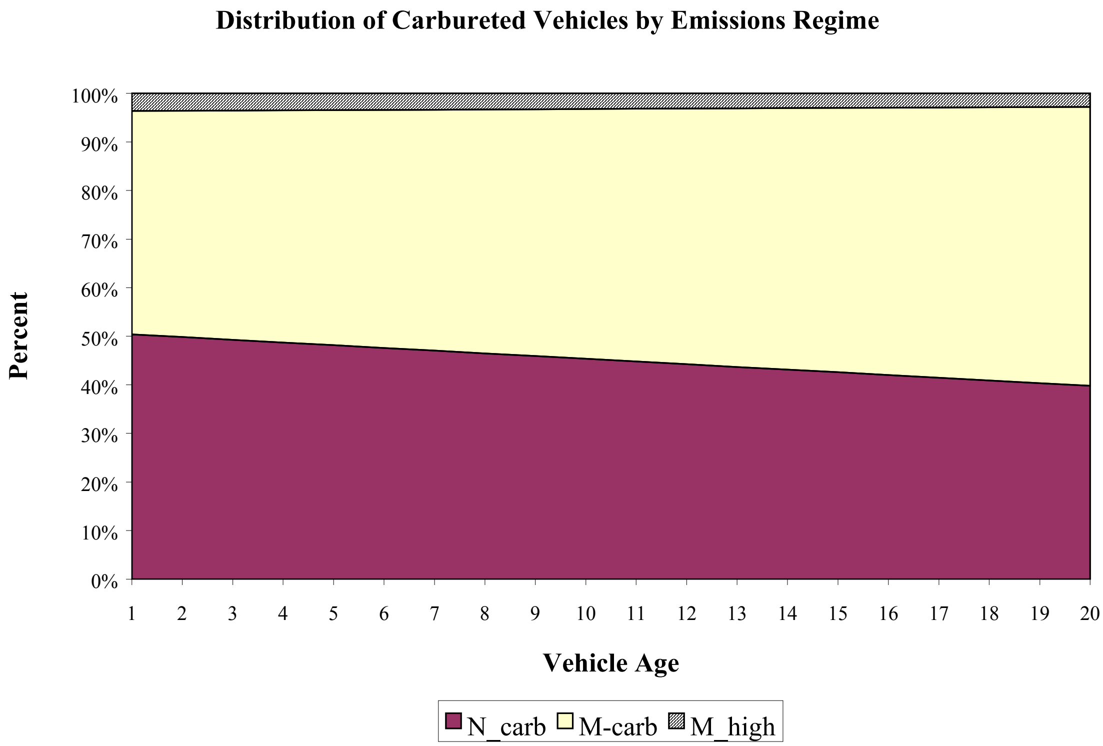
Where:
F_reg is the fraction of vehicles in a given regime
A & B are the regression coefficients

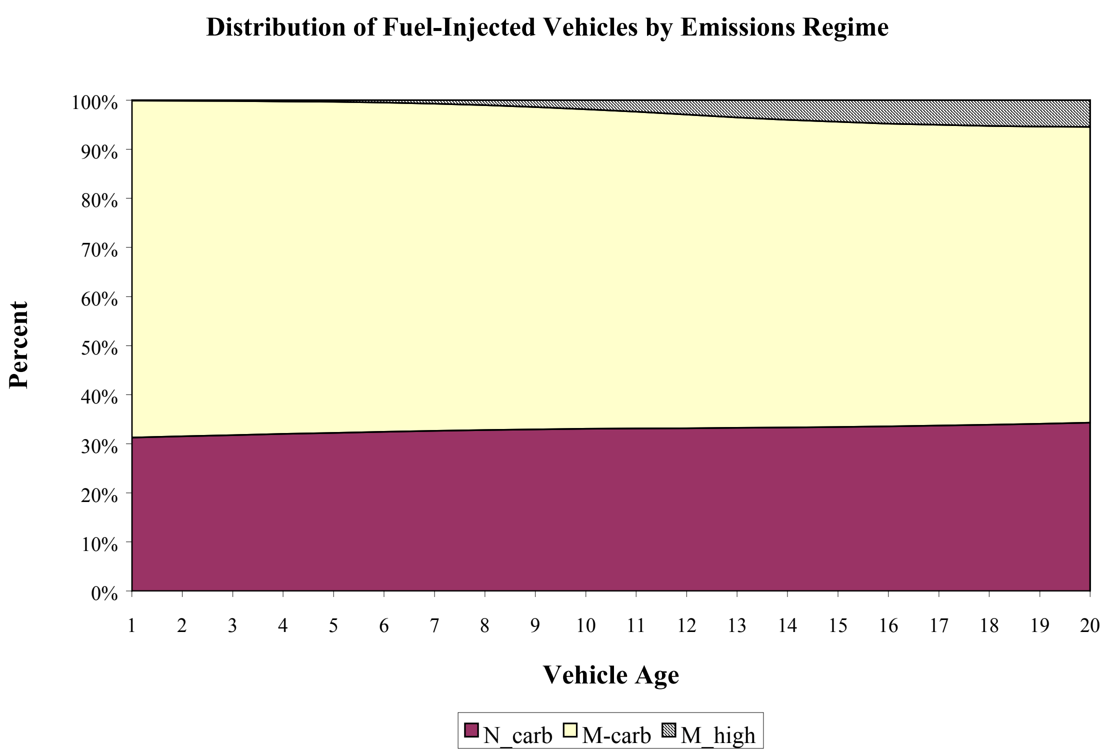
Table 5.1-9 Regime Growth Rates by Fuel Delivery System

Fuel-System	Regime	A	B
Carbureted	Normal	0.509180	-0.005575
	Moderate	0.453626	0.006032
	High	0.036762	-0.000454
Fuel-Injected	Normal	0.310268	0.002625
	Moderate	0.689731	-0.002625
	High	0.06/(1+120*EXP(-0.4*AGE))	
Fuel-Injected OBD2	Normal	0.310268	0.002625
	Moderate	-0.101911	0.014559
	High	0.03/(1+120*EXP(-0.4*AGE))	
Fuel-Injected Near Zero Vehs OBD2	Normal	0.310268	0.002625
	Moderate	-0.101911	0.014559
	High	0.03/(1+120*EXP(-0.4*AGE))	

Figure 5.1-1 shows the distribution of vehicles as a function of vehicle age and by fuel metering system.

Figure 5.1-1 Regime Growth Rates as a Function of Fuel-Delivery System





5.1.5.1 Regime Growth Rates for OBDII Equipped Vehicles

Beginning with the 1996 model year passenger cars, light and medium duty trucks are required to be equipped with an On-Board Diagnostic II (OBDII) system. This system is designed to identify malfunctions that increase emissions by 1.5 times the standard, and illuminate the malfunction indicator light. The OBDII system also stores a fault code identifying the malfunction. Beginning in 1996, the OBDII system on vehicles certified to the enhanced evaporative standard is required to perform a check that will detect vapor leaks from holes greater than 1 millimeter in size. In addition, the system also performs a functional check of the purge valve. The OBDII system is only required to perform a functional check of the purge valve for vehicles not certified to the enhanced evaporative standard. These checks will ensure that malfunctions in the evaporative control system are promptly identified, however, when this repair occurs is dependent upon the consumer. Staff has assumed:

1. There is no growth of moderates for the first 70,000 miles since these vehicles would be immediately repaired under manufacturer warranty. After 70,000 miles the population of moderates would increase. This assumption is based on Table 5.1-10, which shows the number of vehicles with liquid and vapor leaks in the malperforming vehicle data set. The majority of fuel-injected vehicles had vapor leaks with one exception that had a leaking fuel injector. Staff believes that the leaking injector and other vapor leaks would have been identified by the OBDII system.
2. During a smog check, the OBDII system will identify 95 percent of the vehicles in the moderate emissions regime.
3. Vehicles upon repair will migrate to the normal emissions regime. This assumes that the repair correction efficiency is 100 percent. This is based on the fact that the mechanic has to perform a correct repair in order to deactivate the malfunction indicator light.

Please note the OBDII system as designed can only detect vapor leaks, not liquid leaks. However, staff has assumed that by identifying the vapor leaks it will preclude liquid leaks from occurring.

Table 5.1-10 Number of Vehicles with Liquid and Vapor Leaks by Emissions Regime

Fuel-System	Liquid	Vapor
Carbureted	19	16
Fuel-Injected	1	8

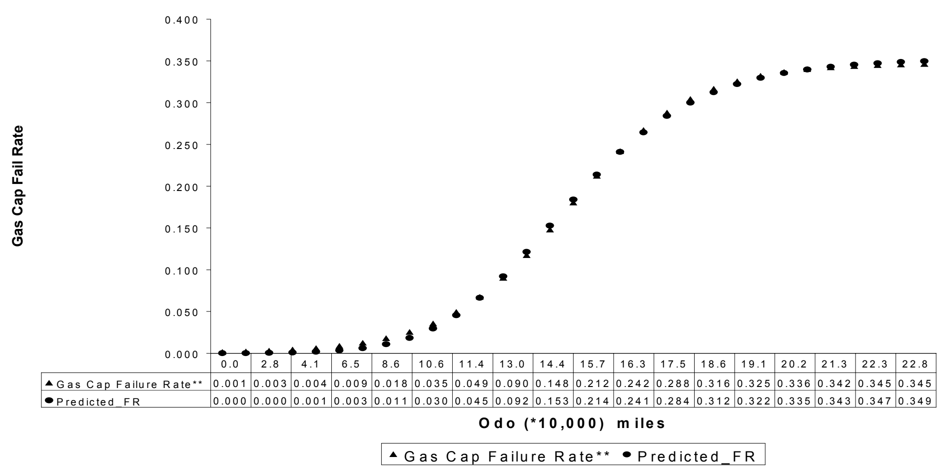
5.1.5.2 Regime Growth Rates for Vehicles Certifying to the Near Zero Evaporative Emissions Standard

Vehicles certifying to the near zero evaporative emissions standard will be phased in beginning with the 2004 calendar year. This requires the combined hot soak plus multi-day diurnal evaporative standard to be reduced from the current 2 grams per test to 0.5 grams per test for passenger cars. While this standard is only designed to reduce hot soak and diurnal emissions; manufacturers will have to design more durable evaporative control systems which will reduce the number of high emitting vehicles (Equation 5.1-2) by a certain percentage. To determine this percentage staff reviewed data collected by Automotive Testing Laboratories (ATL)[2] under contract to the American Petroleum Institute and the CRC, and concluded that the frequency of high emitting vehicles would be reduced by 50% for vehicles certifying to the enhanced and near zero evaporative emission standards. This percentage was determined by reviewing the failure modes of the 22 vehicles found with evaporative system defects and using engineering judgement to decide which failures would not occur on vehicles certified to the near zero evaporative emissions standard. Appendix 5.1-B contains a table describing these vehicles and also lists the defects. An asterisk denotes failures that will not occur in vehicles certified to the near zero evaporative emissions standard.

5.1.6 Effect of Inspection and Maintenance

The distribution of vehicles by emissions regime will change when the vehicles undergo a smog check. In California, the repair mechanics are required to inspect vehicles for leaking or missing gas caps. In 1996 the Bureau of Automotive Repair conducted a roadside inspection test and performed the gas cap test on all vehicles. Figure 5.1-2 shows the observed and predicted gas cap failure rates as a function of the vehicle odometer.

Figure 5.1-2 The Observed and Predicted Gas Cap Failure Rates by Odometer



	0.0	2.8	4.1	6.5	8.6	10.6	11.4	13.0	14.4	15.7	16.3	17.5	18.6	19.1	20.2	21.3	22.3	22.8
Gas Cap Failure Rate**	0.001	0.003	0.004	0.009	0.018	0.035	0.049	0.090	0.148	0.212	0.242	0.288	0.316	0.325	0.336	0.342	0.345	0.345
Predicted_FR	0.000	0.000	0.001	0.003	0.011	0.030	0.045	0.092	0.153	0.214	0.241	0.284	0.312	0.322	0.335	0.343	0.347	0.349

The function used to predict the failure rate is:

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[2] Raw Fuel Leak Survey in I/M Lanes, prepared for the API and the CRC by Dennis McClement, ATL, 10 June, 1998

$$GC\_FR = k/(1+((k-n)/n)*EXP(-r*odo)) \qquad \textbf{(5.1-4)}$$

Where:
GC_FR is the fraction of vehicles failing the gas cap test
k = 0.3531113949
n = 0.000093504
r = 0.5529518365
odo is the vehicle mileage divided by 10,000

Figure 5.1-2 shows the fraction of all vehicles that fail the gas cap test as a function of vehicle mileage. It is assumed that vehicles in the moderate emission regime are identified by the gas cap test since vehicles with vapor leaks dominate this regime. The number of vehicles that get moved to the normal regime is calculated by subtracting the gas cap failure rate from the percentage of moderates.

This methodology assumes that the identification and repair correction rates are 95 percent. The gas cap inspection test will mainly identify vapor leaks from poorly sealed, missing or damaged gas caps. However, vapor leaks can occur from other sources within the evaporative control system. Ideally, one should ascertain what fraction of the total vapor leaks result from vehicles with leaking gas caps. These vehicles will be identified and repaired under the current smog inspection test.

5.1.7 RVP and Temperature Correction Factors

CARB's running loss data (used in modeling the RVP and temperature correction factors or RVP&TCF) consists of data collected during various in-house research projects and data supplied by the USEPA. These data are fragmented in that the vehicles were not tested over the entire range of fuel RVPs or over a single prescribed driving cycle. In order to develop an RVP&TCF for running losses, the modal data were normalized with respect to testing conducted using 9.0 RVP fuel at a temperature of 95^{o}F. The majority of the vehicles were tested under these conditions.

This data set was then analyzed using SAS to determine if the RVP&TCF vary between passenger cars and light-duty trucks or with fuel metering system or by model year. Staff found that the RVP&TCF varied by fuel metering system (carbureted, TBI and PFI). However, for modeling purposes it was decided to combine the TBI and PFI vehicles. There were 126 carbureted and 308 TBI/PFI vehicles that were tested with 9.0 RVP fuel at 95^{o}F and at other fuel/temperature conditions. Equations 5.1-5 and 5.1-6 describe the multiplicative RVP&TCF applicable to carbureted and fuel injected vehicles, respectively.

Carbureted Vehicles

$$RVP\&TCF = \underline{(1.2293 + Time*(0.0002*RVP*Temp - 0.0091*rvp - 0.0006*Temp))} \qquad \textbf{(5.1-5)}$$

$$(1.2293 + 0.00735*\text{Time})$$

Fuel Injected Vehicles

$$\text{RVP\&TCF} = \frac{(1.0858 + \text{Time}*(0.0003*\text{RVP}*\text{Temp} - 0.0144*\text{rvp} - 0.0009*\text{Temp}))}{(1.0858 + 0.00615*\text{Time})} \quad \textbf{(5.1-6)}$$

Where:

Time is engine time-on in minutes.
Temp. is the ambient temperature (^oF) experienced during the trip.
RVP is Reid Vapor Pressure (a measure of fuel volatility) in pounds per square inch.

Domain

The equations described above are only valid over the following range:
RVP= 6.5 – 13.0
Temperature = 80 – 110 ^oF
Time = 0 – 60 minutes

Basically, if the RVP is less than 6.5 then the RVP term is set to 6.5. Similarly, if the ambient temperature is less than 80^oF then the temperature is set to 80^oF. If the trip is longer than 60 minutes then the time is set to 60 minutes.

Equations 3 & 4 are only valid over the domain mentioned above because this incorporates most of the test data. Outside of this range, the RVP&TCF equation and correction factors become unstable. Figures 5.1-3 and 5.1-4 show the change in the RVP&TCF for carbureted and fuel-injected vehicles, respectively, for trip lengths of 10 and 60 minutes.

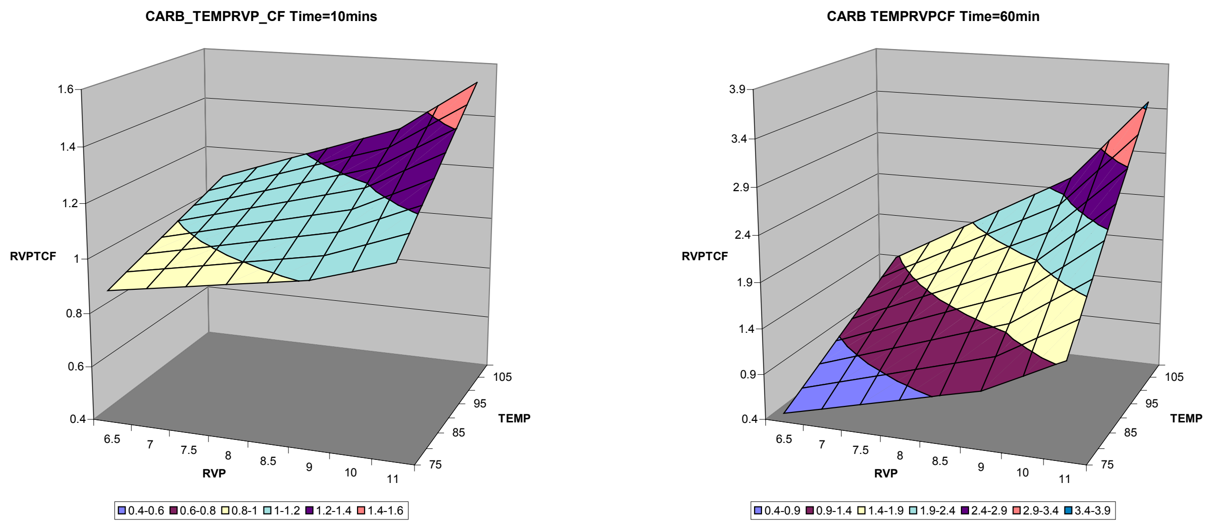

Figure 5.1-3 <u>Change in the RVP&TCF as a Function of Trip Length for Carbureted Vehicles</u>

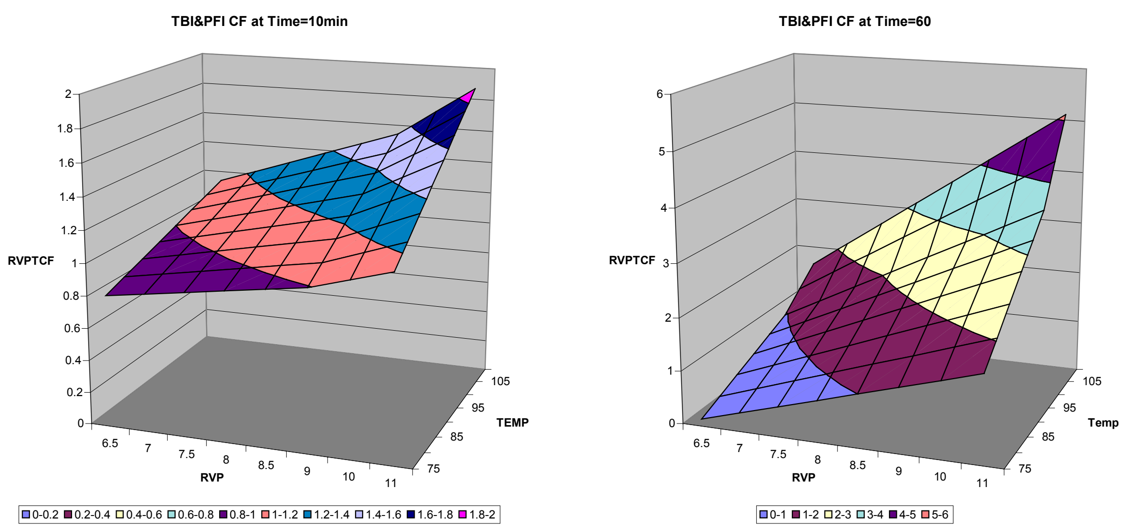

Figure 5.1-4 <u>Change in the RVP&TCF as a Function of Trip Length for Fuel-Injected Vehicles</u>

5.1.8 Discussion and Recommendations

One of the weaknesses of this analysis is with the estimation of the regime growth rates. Ideally the regime growth rates should be calculated for each technology group and vehicle type. However, lack of data necessitated the estimation of regime growth rates by fuel metering system. This assumption is valid if the population of normal, moderate and high emitting vehicles is the same across all carbureted or fuel-injected technology groups. However this assumption may not apply to situations where a particular technology group has a lower percentage of high emitting vehicles than another technology groups simply because the definition of normal, moderate and high changes by technology group. Staff recommend that in future surveillance programs all vehicles should be subject to a single modal LA4 running loss test. This information is necessary in assessing/revising the regime specific growth rates.

In estimating the benefits from a gas cap test, it is assumed that a vehicle failing the gas cap test has emissions that correspond to a vehicle in the moderate emissions regime. Staff recommend that this be verified given that the regime definition change by technology group. It may be possible that some older vehicles that fail the gas cap test may fall into the normal emissions regime. Ideally, one should determine the fraction of vehicles in each emissions regime and technology group that fail the gas cap test. This is the fraction most likely to get repaired under the current smog check.

Appendix 5.1-A

Table 5.1-A1 shows the emission rate of fuel-injected cars and trucks not subject to the enhanced evaporative running loss standards.

Table 5.1-A1

				Intercept A	Time B	Time^2 C	Odometer D	Age E
Cars	TBI/PFI	All	Normal	-0.1115497	0.0223147	0	0	0.00800653
			Moderate	-0.12943963	0.11137024	0	0	0
			High	-1.48947344	0.60721658	0	0	0
Trucks	TBI/PFI	All	Normal	-0.18308557	0.00961453	0	0	0.0213216
			Moderate	-2.08792222	0	0.00688323	0	0.27679645
			High	-1.48947344	0.60721658	0	0	0

The enhanced evaporative running loss regulation requires vehicles at 100,000 miles to meet the 0.05 grams per mile standard when tested at 105°F over three back-to-back LA4's. In order to estimate the emission rates for vehicles subject to this standard, staff has assumed that this standard will be met at 100,000 miles or by a 9-year-old vehicle using 7.0 RVP fuel, when tested at 105°F. The average time to complete three back-to-back LA4's is 75 minutes. Using the equations in Table 5.1-A1, the emissions at the end of 3 LA4's are:

Cumulative emissions (grams) at time=75 minuntes, age=9 years and odometer =100,000 miles				
				grams
Cars	TBI/PFI	All	Normal	1.634
			Moderate	8.223
			High	44.052
Trucks	TBI/PFI	All	Normal	0.730
			Moderate	39.121
			High	44.052

These emissions are then adjusted with respect to the temperature (105°F) and fuel RVP (7.0) used during vehicle certification. The RVP&TCF are calculated by substituting these values in to equation 2 and the result is 1.78567. Table 5.1-A2 shows the temperature and RVP adjusted emission rates, which were calculated by multiplying the emissions in Table 5.1-A2 by RVP&TCF.

Table 5.1-A2

	Car	Truck
	Total grams per 75 mins	
Normal	2.918	1.303
Moderate	14.684	69.858
High	78.662	78.662

The running loss emissions from vehicles meeting the enhanced evaporative standard is: 3*7.5*0.05=1.125 grams. In order to meet these standards the emission rates from cars and trucks in the normal emission regime must be reduced by 61.45% and 13.68%, respectively. The new rates are calculated by multiplying the car and truck emission rates by 0.38554 and 0.86315, respectively.

Appendix 5.1-B

Table 1.
Leaking Vehicle Descriptions

Veh	MY	Make	Model	Eng	Fuel	Class	Comment
5	80	CHEV	CUSTOM 10	5.0	Carb	Leak	FUEL LINE TO PUMP LEAK AT HOSE CLAMP DUE TO PINCHED HOSE.
12*	86	OLDS	CUTLASS	5.0	Carb	Gross	FUEL INLET AND FRONT OF CARB 1 DROP EVERY 5 SECONDS. LEAKING AT BASE OF FUEL FILTER 1 DROP EVERY 5 SECONDS. FUEL PUMP, 1 DROP EVERY 20 SECONDS.
71*	86	DODGE	OMNI	2.6	Carb	Gross	LEAKING 1 DROP EVERY 30 SECONDS AT CARB.
82	74	DODGE	VAN	---	Carb	Leak	HEAVY SEEPAGE AT FUEL FILTER, NOT QUITE A DRIP
131*	85	CHEV	MONTE CARLO	5.0	Carb	Gross	LEAKING AT FRONT OF CARB AND FUEL FILTER. GAS ODOR
153*	74	VW	BEETLE	1.6	Carb	Gross	CARB LEAKED ON SIDE. OWNER MADE PLUG WITH EPOXY; STILL LEAKS.
178*	82	TOYOTA	TERCEL	1.5	Carb	Leak	SMALL LEAKAGE AT SIDE OF CARB, LEAKING TO MANIFOLD. SLIGHT ODOR.
183*	73	FORD	F100	5.9	Carb	Leak	VERY SMALL DROP ON CARB AT ACCELERATOR PUMP. LESS THAN ONE DROP EVERY 30 SECONDS. SLIGHT ODOR.
285*	76	CHEV	CORVETTE	5.7	Carb	Leak	SLIGHT LEAK IN FRONT OF CARB-1"ON PAPER TOWEL. SLIGHT ODOR
324*	72	FORD	MUSTANG	5.8	Carb	Leak	SMALL DRIP ON FRONT OF CARB. AT FUEL FILTER, MORE THAN 1" ON TOWEL. SLIGHT ODOR.
326	73	BUICK	WAGON	5.7	Carb	Leak	FUEL LINE CRACKED AT FUEL FILTER, ELECTRIC TAPE USED TO TRY TO REPAIR DRIP. SLIGHT ODOR.
372	80	CHEV	SILVERADO	5.7	Carb	Leak	SMALL LEAK AT FRONT OF CARB AT FUEL FILTER APPROX. 1" ON PAPER TOWEL. SLIGHT ODOR.
375	86	MERCURY	SABLE	3.0	PFI	Leak	HOSE FROM FILLER TUBE TO TANK NEEDS REPLACED-LIGHT DRIPPING. STRONG ODOR UNDER PASSENGER REAR SIDE OF CAR.
665	85	BUICK	CENTURY	2.5	TBI	Leak	LEAKING AT FUEL INLET OF THROTTLE BODY. GAS ODOR
706*	82	MERCURY	LYNX	1.6	Carb	Leak	LEAKING AT FRONT OF CARB AND FUEL FILTER. GAS ODOR
715*	85	FORD	F250 PICKUP	7.4	Carb	Leak	LEAKING AT FRONT OF CARB AND FUEL FILTER. GAS ODOR
722	86	PLYMOUTH	RELIANT	2.2	TBI	Leak	LEAKING AT FUEL INLET OF THROTTLE BODY. GAS ODOR
747*	85	OLDS	CUTLASS	5.0	Carb	Leak	LEAKING AT FRONT OF CARB AND FUEL FILTER. GAS ODOR
786*	83	BUICK	SKYLARK	2.8	Carb	Leak	LEAKING AT FRONT OF CARB AND FUEL FILTER. GAS ODOR
863	84	CHEV	CAVALIER	2.0	TBI	Leak	LEAKING AT FUEL INLET OF THROTTLE BODY. GAS ODOR
949	83	OLDS	OMEGA	2.5	TBI	Leak	LEAKING AT FUEL INLET OF THROTTLE BODY. GAS ODOR
964	79	VW	RABBIT	1.7	Carb	Gross	GAS TANK DRIPPING 1 DROP EVERY 3 SECONDS. NEEDS TANK REPLACEMENT.

Gross leaks - 4 vehicles
Leaks (liquid but less than gross) - 18 vehicles
An asterix denotes vehicles that will not incur defects if designed to meet zero evap standards.